ENVIRONMENTAL PROTECTION

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TECHNOLOGICAL, ENERGY, AND ENVIRONMENTAL ASPECTS OF COLLECTING AND RECYCLING OF CULLET (A Review)

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The current situation with respect to collecting, preparation, and recycling of cullet abroad and in the CIS countries is discussed. Information concerning cullet recycling received from Russian and CIS glass factories is summarized.

The efficient, integrated, and environmentally safe use of materials in the glass industry, which consumes a lot of material resources, is an important economic challenge. In this context the value of glass scrap is increasing [1 – 4] and the areas of application of cullet are constantly expanding due to research carried out by domestic and foreign researchers. Cullet is now being used in glass production (recycling of reverse cullet in glass melting); in decorative materials (glass claydite, porous claydite, glass Keramite, Uzorite, etc.), fiber glass, and microballs; in the production of construction and heat-insulating materials (brick, facing tiles, foam materials); in "glassphalt" used as road paving and sealing compositions; in abrasive materials; and as a filler in composite materials such as paints, plastics, and rubber [2 – 13].

The recycling of glass waste is necessary since this type of waste neither burns, nor rots, nor decomposes. Cullet is accumulated at production and construction sites, contaminates residential districts, land, and water reservoirs, causes injuries at recreation sites, and comprises a substantial share of household waste. Thus, the content of cullet in household waste is 9.7% in the USA, 8% in Great Britain, 5% in Canada, and 5.5% in Japan. In Russia, cullet is the third in volume (after paper and food waste) in the composition of household waste, namely, 12% [2].

West European countries (Germany, France, Great Britain, Italy, Spain, Austria, Belgium, etc.) and the USA where cullet is the main source of material for container glass production have implemented efficient systems for cullet collection and have developed regulations and technologies for cullet utilization, sorting, cleaning, processing, and recycling. Special waste containers (of white, green, and brown colors) are installed at residential quarters at crossroads and places of probable accumulation of cullet.

Many countries, in addition to the stationary containers, also use the mobile "door to door" or "house to house" method of cullet collecting which involves consecutive touring of companies and residents which are provided with special boxes for cullet collection [14]. As the result of all this, the amount of cullet collected from the population and industrially recycled in West Europe has substantially grown over the last 25 years. Figure 1 presents data on recycling of container glass collected from the population in Germany. The amount of collected cullet in 1994 increased 1.6 times as compared to 1974, and the amount of recycled cullet increased 18.7 times. Thus, the extent of cullet recycling grew from 6.5 to 75%.

The highest volumes of cullet recycling (in absolute values) are found in Germany, France, and Italy (2.8, 1.3, and 0.9 million tons, respectively), whereas the percentage of cullet utilization is at the highest in Switzerland, Austria, Germany, and Norway: 84, 776, 75, and 75%, respectively (Table 1). Up to 50% glass containers in West European countries are now made of recycled cullet processed by specialized companies [15].

Conversion of glass cullet into the main glass batch component requires certain adjustments in the glass-melting technology. Thus, introduction of up to 70% cullet decreases

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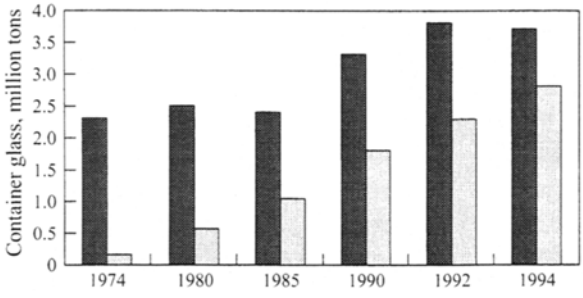

Fig. 1. Amount of container glass collected from population ■ and industrially recycled ▨ in Germany.

the temperature of the termination of silicate-forming reactions by 60 – 80°C and increases the dissolution rate of residual quartz, as a consequence of which the glass formation interval is narrowed by 250 – 300°C. Therefore, it is recommended to reduce fuel consumption in glass melting by 1 – 1.5% per each additional 5% cullet above 25% [16].

At the same time, the process of glass melt clarification is delayed due to the decreased total number of bubbles, a decrease in their mean radius and, accordingly, a decreased speed of bubble rising; the crystallization temperature interval grows, the crystal growth rate is increased, and the microinhomogeneity of glass becomes higher. Therefore, it is recommended to additionally introduce soda and clarifiers into the batch to compensate for the variations in the chemical composition of glass and to increase the speed of bubble rise, as well as adjust the technological parameters of the glass melting and molding while strictly observing the ratio between the batch and the cullet [16 – 18].

TABLE 1

Country	Amount of collected cullet	
	thou. tons	%
Germany	2800	75
France	1300	48
Italy	890	54
Great Britain	492	28
Spain	371	31
Netherlands	367	77
Switzerland	242	84
Belgium	235	67
Austria	203	76
Denmark	108	67
Sweden	95	56
Portugal	71	32
Greece	37	29
Norway	36	72
Finland	28	50
Ireland	28	31

Introduction of an increased amount of cullet alters the redox potential of the batch and requires constant monitoring of the melt oxidizing activity. The furnaces for container glass melting in Germany are equipped with special sensors located at the first pair of burners, which makes it possible to timely prevent undesirable deviations in the redox potential of the glass melt [19, 20].

Clear glass cullet in our country was always in short supply. The main reason is the absence of selective collection of cullet, which hampers its sales [21]. Collection, transportation, and especially sorting of waste are the most costly operations in waste utilization, which comprise up to 75% of the total recycling cost [2]. The Recycled Resources Direction (Soyuzglavvrorresursov) of the Gossnab of the USSR, the Tsentrosoyuz, and other entities responsible for cullet collection were not equipped for sorting, washing, and high-quality separate storing of cullet, and had no containers for glass waste collecting [1, 2, 14]. As a consequence, the collected cullet did not meet the requirements of OST 21-7–74 and the currently in force TU 21-RSFSR-137–89, according to which the presence of other groups of glass, sand and clay impurities, corks, and paper should not exceed 2%. At the same time, the above requirements are significantly less strict than the foreign regulations (Tables 2 and 3). For instance, as the quality of clear container glass constantly improves, the permitted amount of tinted glass in Germany is only 50 g per 1 ton of clear cullet, which is equal to 0.005%. This high degree of purification is accomplished by careful processing, including manual sorting of cullet [21].

With the aim of getting reliable and full information on the cullet situation, questionnaires related to this problem were sent in 1997 to 200 glass factories of the CIS countries, the 20 largest waste collecting companies of the CIS, and 15 Regional Administrations of Russia. The questionnaires

TABLE 2

Glass	Type of impurity	Average content in the cullet, g/ton		
		1981	1987	1994
Clear	CPS*	115	51	31
	Al	54	9	2
	Pb	18	2	1
	Fe	1.6	0.5	1.7
Green	CPS	197	46	23
	Al	234	69	17
	Pb	98	12	7.5
	Fe	1.6	0.05	1.4
Amber	CPS	234	57	42
	Al	173	36	8
	Pb	87	8	3
	Fe	0.4	0.1	1.4

* Ceramics, porcelain, stones.

TABLE 3

Year	Mass content in the cullet, %					
	clear		green		amber	
	Fe_2O_3	Cr_2O_3	Fe_2O_3	Cr_2O_3	Fe_2O_3	Cr_2O_3
1984	0.077	0.008	–	–	0.300	0.026
1987	0.076	0.005	–	–	0.300	0.033
1990	0.077	0.005	0.353	0.196	0.309	0.043
1994	0.077	0.004	0.363	0.214	0.317	0.040

were made up by the Chair of Glass at the Belgorod Academy of Construction Materials and the editorial board of *Steklo Mira* journal and concerned the quantity and quality of recycled cullet, the sources and volumes of cullet formation in the regions and at the companies, the existence of specialized cullet-collecting and cullet-processing companies in the regions, etc.

Replies were received from 25 factories and entities in Vladimir, Tver', Moscow, Lipetsk, and Rostov regions of Russia, Ukraine, Belarus, and Moldova. This amounted to about 10% of the sent questionnaires and did not allow for getting a completely objective picture of the cullet situation all over the CIS. However, the obtained data were analyzed and summarized [22].

It was noted that virtually all glass factories which submitted their replies had increased the content of cullet in the batch (batch : cullet ratio varied from 70 : 30 to 50 : 50) and actively used purchased cullet. The spread of prices for cullet is significant: from 15 – 20 (Belarus) to 77 – 100 (Russia) US dollars per 1 ton.

Most producers complain about the shortage of clear cullet. This is natural since nobody in the CIS is currently employed in sorting cullet. The manufacturers of clear glass containers often use semi-white cullet, which substantially deteriorates the quality of glass. There are virtually no specialized companies in the regions to collect and process cullet. Cullet is supplied to glass factories by construction companies, milk and food factories, breweries, liquor factories, and glass manufacturers. Most cullet consumers are guided by TU 21-RSFSR-137 – 89 as the regulatory document for cullet.

Some glass factories have opened on their premises special facilities for cullet collection (by weight) from the population (Tiraspol' Glass Container Factory, JSC Belevrotara (town of Lida)) [23].

The present review does not aspire to fully describe the current situation in cullet recycling. However, the problems of collection, processing, and use of cullet in Russia and the CIS call for urgent solutions.

REFERENCES

1. *Collection, Processing, and Recycling of Cullet. A Review* [in Russian], Issue 1, VNIIÉSM, Moscow (1987).
2. R. G. Melkonyan, "Collection and recycling of glass waste," *Zhil. Kommun. Khoz.*, No. 1, 35 – 38 (1995).
3. R. G. Melkonyan, "Cullet. A second life," *Steklo Mira*, No. 4, 57 – 59 (1997).
4. R. G. Melkonyan, "Utilization of cullet," *Steklo Mira*, No. 1, 27 – 28 (1998).
5. R. I. Sevost'yanov and N. N. Shcheglova, "Use of cullet," *Stek. Prom.*, Issue 4, 4 – 8, VNIIÉSM, Moscow (1988).
6. N. N. Shcheglova, "Use of cullet in construction and facing materials," *Stek. Prom.*, Issue 5, 5 – 7, VNIIÉSM, Moscow (1988).
7. N. N. Shcheglova, R. I. Sevost'yanov. K. S. Katkova, and G. M. Mikerova, "Use of cullet in glass melting," *Stek. Prom.*, Issue 7, 2 – 4, VNIIÉSM, Moscow (1988).
8. "Glass recycling rises sharply," *Am. Glass Rev.*, **107**(1 – 2), 10 (1987).
9. A. G. Tatarintsev, V. A. Gaivoronskii, and N. G. Kisilenko, "Glass claydite made of purchased cullet," *Steklo Keram.*, No. 7, 25 – 26 (1988).
10. R. G. Melkonyan, "Use of industrial waste and cullet in production of new decorative facing materials. A Review," in: *Economics and Rational Use of Raw, Fuel, and Other Mineral Resources* [in Russian], Issue 11, TsNIITÉ i MS (1989).
11. L. G. Samkova, G. K. Geizer, and R. N. Aleksandrova, "Picture tube cullet used in production of household glassware," *Steklo Keram.*, No. 1, 8 – 9 (1990).
12. S. V. Denisova, "Production of glassware based on cullet," *Steklo Keram.*, No. 1, 29 (1992).
13. N. F. Zhernovaya and V. I. Onishchuk, "Use of cullet in production of porous construction materials," *Izv. Vuzov. Ser. Stroitel'stvo*, No. 10, 99 – 101 (1996).
14. N. N. Shcheglova, L. P. Desnitskaya, and R. I. Sevost'yanov, "Cullet collection and processing systems," *Glass Ind.*, No. 3, 3 – 7, VNIIÉSM, Moscow (1988).
15. "Cullet. A second life. World experience of collection, processing, and recycling of cullet," *Steklo Mira*, No. 1, 56 – 62 (1997).
16. T. V. Bartkovskaya, *Development of Glass-Melting Technology with Increased Cullet Production* [in Russian], Author's Abstract of Candidate's Thesis, Moscow (1989).
17. E. K. Polokhlivets, I. A. Klyuchnik, and V. I. Kiyan, "Specifics of technology of continuous production of figured sheet glass with increased cullet content," *Steklo Keram.*, No. 3, 3 – 6 (1995).
18. E. K. Polokhlivets, I. A. Klyuchnik, V. I. Kiyan, and N. S. Latysh, "Production of reinforced glass with increased cullet production," *Steklo Keram.*, No. 12, 3 – 6 (1995).
19. "Redox control in glass melt," *Glass Sci. Technol.*, **71**(7), 5 (1998).
20. N. A. Schaeffer, *Glass Technology* [in Russian], CTI-Print, Kishinev (1998).
21. R. I. Sevost'yanov and N. N. Shcheglova, "Organization of glass cullet collection in the USSR," *Stek. Prom.*, Issue 10, 11 – 14, VNIIÉSM, Moscow (1986).
22. V. N. Bolotin and N. I. Min'ko, "Struggle for the cullet. The beginning...," *Steklo Mira*, Issue 1, 62 – 63 (1997).
23. V. N. Bolotin, "Cullet comes to the glass factory," *Steklo Mira*, Issue 4, 59 (1997).